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THE FOREST SERVICE AND HERBICIDES

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Cover: A Douglas-fir seedling struggles to survive surrounded by encroaching brush.

THE FOREST SERVICE AND HERBICIDES[1/]

FOREWORD

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1/ Technical data adapted from publications by Logan A. Norris, et al.

FOREWORD

The purpose of this paper is to give the whys, hows, results, and consequences of our use of herbicides. It is a resume of the policies, practices and the principles involved. The United States Department of Agriculture policy on pesticides is:

> It is the policy of the Department of Agriculture to practice and encourage the use of those means of effective pest control which provide the least potential hazard to man, his animals, wildlife, and the other components of the natural environment.
>
> For the foreseeable future, pesticides will be necessary tools for the protection of the nation's food and fiber supplies, people, and their homes.
>
> Where chemicals are required for pest control, patterns of use, methods of application and formulations which will most effectively limit the impact of the chemicals to the target organisms shall be used and recommended. In the use of these chemicals, the Department has a continuing concern for human health and well-being and for the protection of fish and wildlife, soil, air, and water from pesticide contamination.
>
> In keeping with this concern, persistent pesticides will not be used in Department pest control programs when an effective, nonresidual method of control is available. When persistent pesticides are necessary to combat pests, they will be used in minimal effective amounts, applied precisely to the infested area, and at minimal effective frequencies.
>
> Nonchemical methods of pest control, biological or cultural, will be used and recommended whenever such methods are available for the effective control or elimination of target pests. Integrated control systems utilizing both chemical and nonchemical techniques will be used and recommended in the interest of maximum effectiveness and safety.
>
> In carrying out its responsibilities, the Department will continue to:
>
> -- Conduct and support cooperative research to find new, effective biological, cultural, and integrated pest control materials and methods;
>
> -- Seek effective, specific, nonpersistent pesticides and methods of application least hazardous to man and his environment;

-- Require pesticide product labels which adequately inform all users of the composition and the proper and permitted use of each formulation;

-- Review and update all pesticide registrations, eliminating any uses not in conformity with current criteria of safety and efficacy;

-- Cooperate with other public and private organizations and industry in the development and evaluation of pest control materials and methods, assessment of benefits and potential hazards in control operations, monitoring for pesticide residues, and dissemination of pesticide safety information.

All users of pesticides, whether in the home, garden, field, forest, or aquatic area or for public health and sanitary purposes, are strongly urged to heed label directions and exercise constant care in pesticide application, storage, and disposal for the protection of people, animals, and our total environment.

The Department commends this policy to all who use, recommend, or regulate pesticides.

/s/ Clifford M. Hardin
Secretary of Agriculture

The need for this resume is caused by the present concern over the declining livability of our environment. Many are questioning the use of chemicals. Herbicides, particularly 2,4,5-T, are also under close scrutiny.

A few studies have suggested the possibility that 2,4,5-T may cause teratogenetic (abnormalities) or effects in the human population. Reports from Viet Nam also indicate this possibility. Scientists are seriously questioning the validity of extrapolating these reports to the actual conditions of use in the United States.

Comparisons between the use of herbicides in Viet Nam and our use in Region 6 for forest spraying are not valid. In Viet Nam, very large contiguous areas (tens of thousands of acres) were sprayed with large fixed wing aircraft without regard to streams or habitations. Many areas were sprayed repeatedly. Dosages were 10 to 12 times greater than those used by the Forest Service. Treated timber areas in Region 6 are scattered, averaging about 25 acres in size, with a

maximum of about 350 acres. On range lands, average size is about 300 acres with a maximum of about 1,000 acres. Unsprayed buffer zones are left along all streams. Application is by helicopter, which results in precise application.

The formulations used in Viet Nam are much more volatile than those used in Region 6.

PART I - SUMMARY

POLICY

The basic policy in Region 6 of the Forest Service on the use of chemicals, including herbicides, is as follows:

1. Chemicals may be used to enhance National Forest resources when no significant hazard to the environment is created.

2. Usage will be based on a biological-economic analysis. Long-term ecological and biological impact, as well as immediate economic gain, will be considered.

3. Only materials and methods will be used which are effective and have the least potential hazard to man, his animals, wildlife and other nontarget components of the environment.

4. The lowest effective dosage of the least hazardous effective material will be used.

5. Possible hazards to the biota will be identified and precautions taken to prevent adverse effects.

6. Only materials registered for the specific use intended will be used and they will be applied in accordance with label directions. The Forest Service will require additional restrictions on specific projects as deemed necessary to protect other resource values.

7. Application of chemicals and poisons will be done only by properly trained and authorized personnel.

8. Federal and State agencies with responsibilities and concern for the environment, public health, and fish and wildlife will be informed in advance of our programs. Where appropriate, consultations and reviews with them will be held. These should be documented. Written comments are desired.

(We have been doing this on our major projects for the last 10 years or so.)

THE NEED FOR USING HERBICIDES

Herbicides are used to increase the productivity of our forests and ranges. Unwanted vegetation is sprayed either to release desirable plants (trees, grass, shrubs, or forbs) or to prepare the site for planting, for fire breaks, safety on roads, range rehabilitations and improvement of game habitat.

The alternatives to spraying are: (1) do nothing and accept less production of timber and forage, or (2) use much more costly hand or machine methods.

Research has demonstrated that some herbicides can be used without harm to human health or to the quality of the environment. Forest Service programs are based on these research findings.

Herbicides do the job at the least cost and, in many instances, with less impact on the environment than machine work. The cost of hand work is several times greater and with limited funds much less work could be accomplished.

By using herbicides safely and responsibly, the maximum return is secured for money expended and can be accomplished without serious impact on the environment.

Herbicides most commonly used in timber management are 2,4-D, 2,4,5-T, amitrole, or a combination of these. These are used to prepare sites for planting, for slash burning or for release of coniferous trees. Not all species of vegetation are equally susceptible to a given chemical. Therefore, specific chemicals are prescribed for specific purposes.

In forest management, 2,4-D, 2,4,5-T, and amitrole are used alone or in combinations to control brushy species and alder which compete with conifers for growing space.

In range management, 2,4-D is commonly used to control sagebrush and rabbit brush, release of grass or other desirable forage or to prepare the sites for seeding to desirable species.

Noxious and poisonous weeds, such as Canada thistle and tansy ragwort, are also controlled by herbicides. Brush along roadsides is sprayed to provide safer driving conditions, and for less expensive maintenance.

BENEFITS OF USE

The cost-benefit ratios are favorable. In a study[1/] in western Oregon, the following results for Douglas-fir were obtained in the six seasons following spraying:

1. Trees 1-2 feet tall at time of spraying grew 178 percent faster than unsprayed control trees.

2. Trees 3-4 feet tall grew 95 percent faster than the unsprayed control trees.

3. Trees 5-6 feet tall grew 75 percent faster than the unsprayed control trees.

4. Trees 7-8 feet tall grew 61 percent faster than the unsprayed control trees.

In another study, [1/] trees 15 feet tall at the time of spraying, five years later were growing 155 percent faster than the unsprayed control trees.

In all cases, diameter growth corresponded to the increased height growth. The needle complement was greater and tree vigor increased.

Herbicide use in range improvement also pays off. As an example, in 1964 about 1,300 acres of sagebrush were sprayed on the Crooked River National Grasslands near Madras, Oregon. Some 800 of these acres were seeded to grass in 1965.

For 15 years prior to the rehabilitation of this range, the carrying capacity averaged 224 cow months per year. In the first three years following rehabilitation, use has averaged 708 cow months per year.

[1/] Lauterbach, Paul G., (Herbicides and Vegetation Management in Forests, Ranges, and Noncrop Lands, 1967) pp. 148-151, Chemical Weeding and release of conifers in western Oregon and Washington in Symposium Proceedings, School of Forestry, Oregon State University and Division of Continuing Education. Oregon State System of Higher Education.

CONSEQUENCES OF USE

Assessment of Hazard

The hazard to man and other non-target biota associated with the use of chemicals (including herbicides) depends on two factors: (1) the toxicity of the chemical, and (2) the potential that an organism will be exposed to a biologically significant dose. Hazard is low if either the toxicity of the chemical or the potential for exposure to a significant dose is low. Hazard is high only if both toxicity and potential for exposure are high. An adequate assessment of the hazard associated with the use of a chemical must consider both toxicity of the chemical and the potential for exposure of an organism.

Toxicity

Toxicity may be described in several ways: (1) lethal toxicity, a large enough dose to cause death, (2) acute toxicity, resulting in a serious and usually prompt biological impact which results from one or a few large doses received over a short interval, and (3) chronic toxicity, which results from many small doses received over a long interval. Acute and chronic toxicity may not cause death, but may reduce the well being of an organism.

The size of the dose and the duration of exposure determine the nature of the response. The threshold response level is the minimum dose which is biologically significant. No direct response is possible if the chemical is not present in quantities greater than the threshold response level. An acutely toxic response can result only from exposure to large doses. A chronic response can result only from prolonged exposure.

Materials vary in toxicity; i.e., the amount it takes to cause death or significant biological impact on an organism. The herbicides commonly used by the Forest Service are quite low on the scale of toxicity; that is, it takes large amounts to be lethal or to cause acute toxicity. Inasmuch as 2,4-D and 2,4,5-T are non-persistent herbicides that are low in toxicity, these conditions do not occur. Therefore, the likelihood of lethal, acute or chronic toxicity to non-target organisms is remote.

Exposure

Exposure of biota to a biologically significant dose is determined by two factors: (1) the initial distribution and amount of the chemical among the four major components of the environment (air, vegetation, ground, and water) following application, and (2) the behavior of the chemical in each component of the environment.

Initial Distribution of Aerially Applied Herbicides

Air.--Some of the fine droplets and vapors from the spray pattern leave the treatment site. These materials may fall out, be washed out, be adsorbed (attached to vegetation, soil, etc.), or be absorbed (taken up by vegetation) from the air. They may also be degraded by chemical, photochemical, or biological means.

Vegetation.--A major portion of the spray material will, hopefully, be absorbed by the plant and translocated from the site of uptake. Some chemical may be volatilized to the air, degraded in place, or bound (adsorbed) to the leaf surface. Major amounts of herbicides may enter the environment of the ground from falling leaves or rain washings.

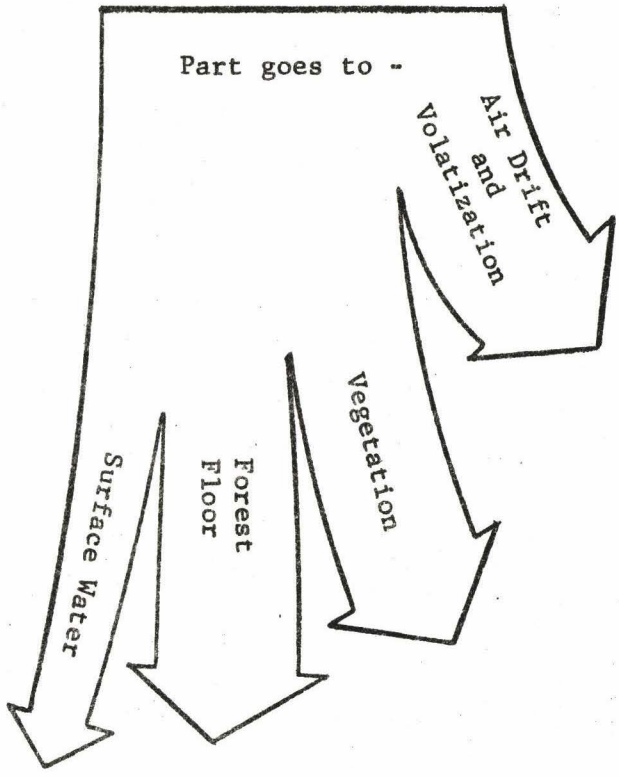
Ground.--The ground is a major interceptor of spray materials due to direct application or subsequent contributions from the air and vegetation. Herbicides on the ground may volatilize into the air, be adsorbed or leached in the soil, washed overland to streams, absorbed by plants, or degraded by chemical, photochemical or biological mechanisms.

Water.--Ground water contamination requires leaching, a slow transport process. Surface water contamination can result from direct aerial application or overland flow of herbicides from the site of application. Herbicides in water may be volatilized to the air, adsorbed (attached to) by stream sediments, absorbed (taken up) by plants, or degraded.

Short-term, high-level herbicide residues result from direct application to the stream surface. They may be largely avoided by excluding streams from treatment areas.

Movement in the environment.--Movement within and among components of the environment is an important aspect of the behavior of herbicides. The following figure shows the distribution of an aerially applied herbicide to the four major segments of the environment.

AERIALLY APPLIED HERBICIDES



1. Movement in water.--Herbicides dissolved in stream or ground water tend to move with the water, but they will not move as fast nor as far as the water. The greater the area of interface between the water and soil, the greater the opportunity for adsorption of chemical from the water. Thus, movement in ground water will be much slower than movement in streams. Downstream movement is an important mechanism in reducing the concentration of herbicides in streams.

2. Movement in and over the ground.--The herbicides will go where the water goes, but not as fast nor as far. Overland flow of water and, therefore, chemical can only occur when the rate of precipitation is greater than the rate of infiltration. This occurs infrequently.

Herbicide movement by leaching and diffusion in the soil profile is a slow process which moves relatively small amounts of chemical short distances. The extent of leaching is determined by the degree and strength of interaction of the chemical with the soil, the temperature, and the amount and speed of water movement through the soil profile. Herbicides are not highly mobile in the soil profile.

3. Movement in vegetation and other biota.--Chlorophenoxy herbicides are systemic chemicals; i.e., they are translocated in the plant from the site of entry to other plant parts. These chemicals are not stored in animal tissues to any significant degree. Experimental evidence shows the chlorophenoxy herbicides are rapidly eliminated in urine and feces. Residence time in the body is short.

4. Movement in the air.--The number and size of droplets less than 100 microns (a micron is one millionth of a meter) in diameter, the elevation of release, wind velocity, and temperature and humidity determine the extent of movement of these small droplets in the air. Vaporization of herbicides depends on the vapor pressure of the chemical and environmental parameters like atmospheric pressure and temperature. Air movement will sweep vaporized herbicides from the treated area. Air movement is closely related to the technology of application. Modifications of spray equipment and operating conditions and the use of low volatile formulations of herbicides can significantly reduce movement through the air. These changes in technology are being incorporated into practice as quickly as they are developed.

Degradation.--Eventually all herbicides are lost by degradation; i.e., they change from one form into another. This can be by photochemical, biological, metabolic, or chemical means. It may occur in the air, soil, water, the vegetation or other biota.

Impact on nontarget organisms.--

1. Impact on man.--There is no evidence of harmful effects on man being caused by 2,4,5-T or 2,4-D as used in forest or range spraying in Region 6.

2. Impact on animals.--Feeding studies with various animals, including deer, have shown that 2,4,5-T or 2,4-D is rapidly excreted. There is no evidence that harmful effects have been caused to wildlife under the condition of use by the Forest Service.

3. Impact on aquatic biota.--The magnitude of stream contamination resulting from herbicide brush control operations can be variable. In the vast majority of operations that have been monitored, the levels of residues observed and their residence time in the stream have not constituted a serious threat to native fish populations. We have learned through experience to recognize and avoid those situations which lead to dangerous levels of herbicide residues in streams. When buffer strips are left along streams, pollution is prevented.

CONCLUSION

In conclusion, it appears that when herbicides are used in low dosages, under strict supervision, on small scattered areas, there is little, if any, impact on nontarget biota.

In herbicides the Forest Service has an important land management tool that we have learned how to use efficiently and with minimum impact on the environment.

PART II - DISCUSSION

BEHAVIOR IN THE ENVIRONMENT

There is much misunderstanding concerning the possible herbicide contamination of the environment. Herbicides are a special class of chemicals with properties that can be used to man's advantage.

The key to the proper use of any herbicide is an adequate understanding of its behavior and how it does its job. Since it is a chemical, it obeys the laws of chemistry and of biology.

If we know the laws of chemistry and biology, the chemical and physical properties of the chemical, and the factors in the environment which affect these properties, we can understand the behavior of chemicals in the environment.

Let's talk now about the behavior of chemicals in the environment with particular emphasis on the behavior of herbicides in the forest, but the principles apply equally well to other chemicals in the environment. That is to say, the laws and properties which govern the behavior of herbicides in the forest environment also govern the behavior of other chemicals in other environments. Behavior differs only in degree.

Before we can assess the impact of an herbicide spray operation on the environment, it is necessary to know what parts of the environment will receive the chemical. Figure 1 depicts the distribution of an aerially applied herbicide to the four major portions of the environment. The amount of herbicide entering each portion of the environment will be determined by the chemical used and the environmental conditions which prevail at the time of application.

AERIALLY APPLIED HERBICIDES

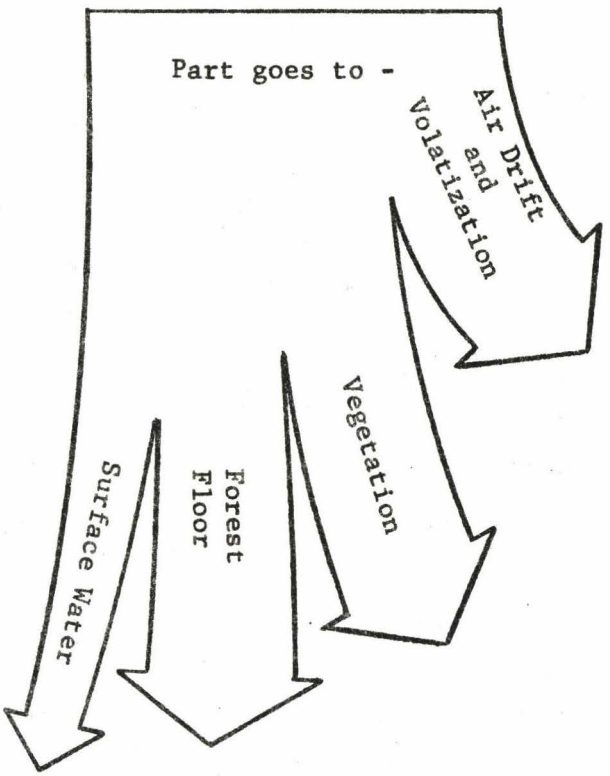


Figure 1.--The distribution of aerially applied herbicides in the forest.

A portion of the spray material is dispersed by the wind as fine droplets. Additional amounts of chemical may be lost through volatilization of spray materials while falling through the air. Most of the herbicide not lost through drift or volatilization is intercepted by the vegetation or the forest floor.

Losses of herbicides in the air may be appreciable, ranging from 20 to 80 percent.

In Region 6 practice where we spray with little wind, moderate temperatures, and using helicopters flying close to the vegetation, the losses in the air are minimized.

Several things can happen to an herbicide in the air. This is the portion which is lost from the spray pattern; i.e., the 20 to 80 percent which does not reach the ground or vegetation.

The loss of aerially applied herbicides to the air represents a potential hazard about which little is known. Chemicals dospersed in the air move elsewhere where they may settle to the earth or be washed out by rain. Ultimately, degradation is the only means by which we are rid of them.

The fate of an herbicide intercepted by vegetation is shown in Figure 2.

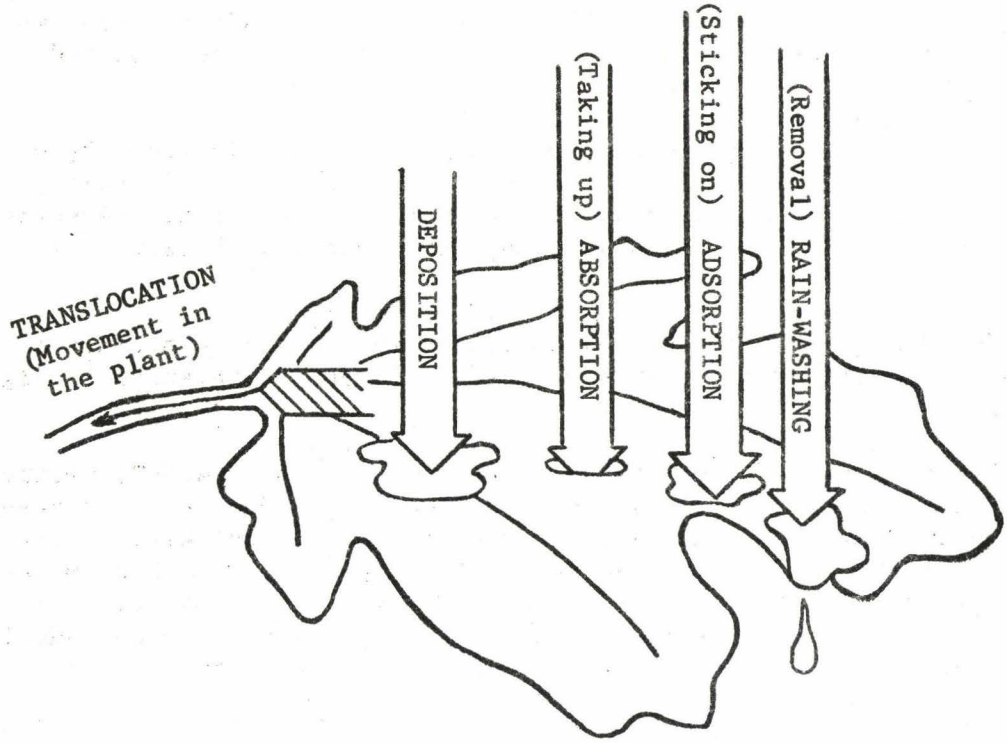


Figure 2.--The fate of an herbicide intercepted by foliage.

For some common brush control herbicides there is limited absorption (taking up) and limited translocation (movement). Through the action of rain, most of the herbicide not absorbed eventually will be washed from the surface of the leaf and reach the forest floor. The remainder of the herbicide on the leaf surface and any herbicide not translocated to other plant parts will also enter the environment of the forest floor due to leaf fall.

Any chemical retained by the plant may be excreted back into the environment through the roots, or it may be stored in some tissue and be released at a later time. Through metabolic activities plants may degrade the herbicide to a material which is not of biological importance.

This must be emphasized--only through degradation is the total amount of the herbicide in the environment reduced. Volatilization, storage, and excretion result only in temporary diversion of chemical and eventual redistribution in the environment.

The forest floor is one of the receptors of aerially applied herbicides. For this reason, the behavior of chemicals in the forest floor is of major importance.

Volatilization of an herbicide from the soil surface does occur. This machanism may be responsible for the loss of fairly large amounts of some herbicides. Herbicides in the soil may also be absorbed through plant roots and be recycled in that system.

Once again we stress that degradation is the only means by which the total amount of an herbicide can be reduced. Volatilization, leaching, and uptake by plants only redistribute the herbicide. Adsorption (adhesion to a surface) is only temporary storage with future release a certainty.

The degradation of several common brush control herbicides in forest floor litter has been studied. The results are shown in Figure 3.

Figure 3 illustrates the degradation of 2,4-D, 2,4,5-T, amitrole and picloram (tordon). These chemicals were degraded but at markedly different rates. Amitrole and 2,4-D were degraded quickly. After 35 days, amitrole recovery had fallen to 20 percent, 2,4-D to 6 percent. In contrast, 2,4,5-T required 120 days to reach a recovery level of 13 percent. Picloram was even more resistant to degradation and after 180 days, more than 65 percent remained in the litter.

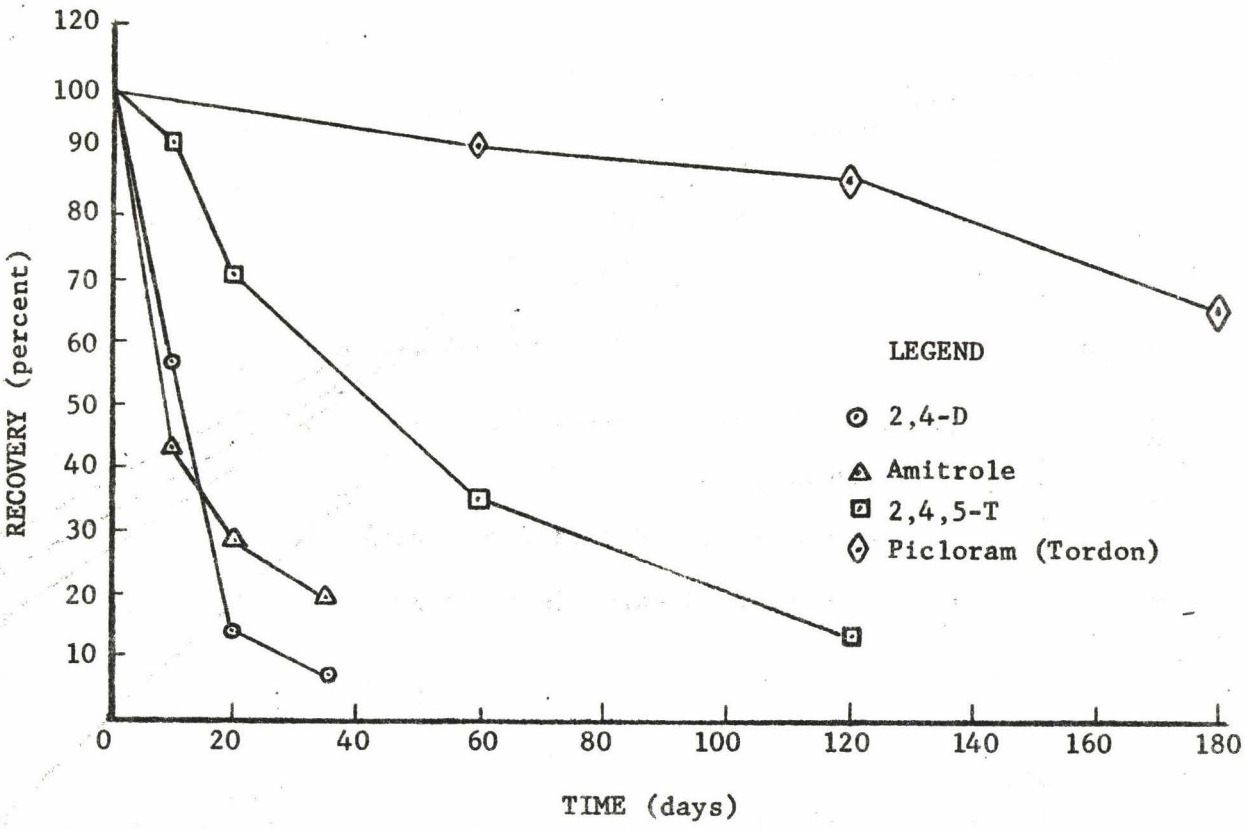


Figure 3.--Degradation of herbicides in forest floor material.

There are some interesting things about the degration of 2,4-D. Figure 4 shows the rate of degradation varies with different formulations. The greatest difference was between the 2,4-D acid and the 2,4-D solubilized acid. In these two formulations the herbicide is in exactly the same chemical form. The difference is the solubilized acid formulation contains several emulsifiers and solvents to make the herbicide more compatible with a water carrier. The difference in degradation rate of these two formulations is not due to differences in the herbicide but rather that one formulation contains additional chemicals. The fact is that the presence of one chemical can influence the degradation of another. In this case, the presence of emulsifiers, solvents, and impurities inhibited the degradation rate of the 2,4-D.

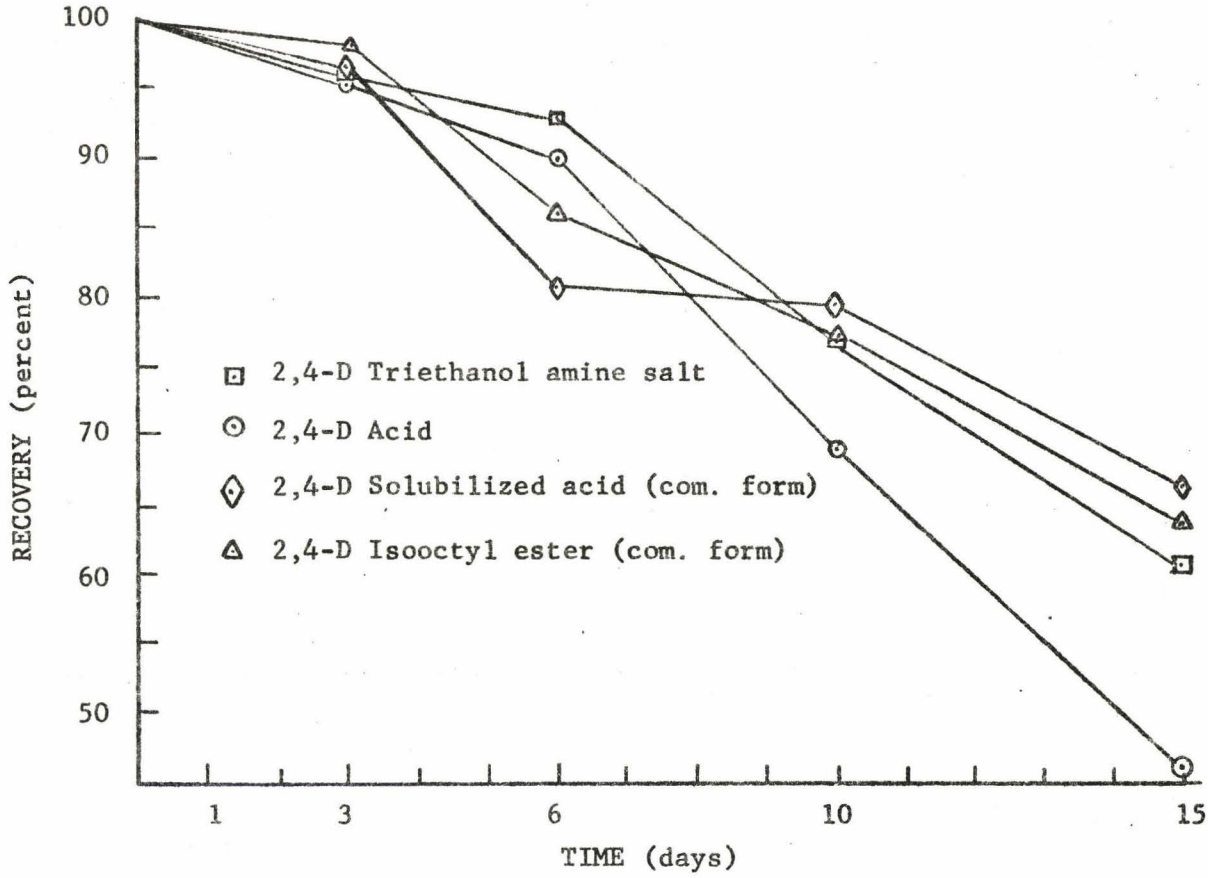


Figure 4.--Influence of formulation on degradation of 2,4-D.

Herbicides are degraded in the environment of the forest floor and in the soil, but the rate of degradation does vary with the treatment. It should be clear that the more herbicide which is degraded the less opportunity there is for redistribution to other portions of the environment such as the air or water.

STREAM CONTAMINATION

Stream contamination is the most immediate and most important expression of environmental contamination in the forest because the water is the habitat for many biological communities and because water represents a critical commodity to downstream users for domestic, commercial, agricultural, and industrial purposes.

Herbicides reach the water in several ways. First of all, the chemical may be applied directly to the surface of the water either intentionally or because of drift from an adjacent area. This type of contamination will occur for only a short period of time and may result in relatively high concentrations of the herbicide.

Additional amounts of herbicide may enter a stream due to absorption of vapors from the air or in rainfall washing it from the air or from foliage. Finally, there is the possibility of movement of herbicide to streams due to leaching through the soil profile or in mass overland flow during periods of intense precipitation.

Considerable research has been done on stream contamination resulting from regularly scheduled spray projects on forest and range lands. Stream contamination resulting from regularly scheduled spray projects on forest and range lands has been studied since 1963. Results from two different watershed containing areas treated with herbicides for brush control in western Oregon follow.

Figure 5 shows the Cascade Creek Watershed (3,450 acres) in the Alsea Basin in the Siuslaw National Forest. It shows the watershed boundaries and location of treatment areas (65 acres), streams, and sample points. Observe the location of boundaries of treatment areas with respect to streams. Low volatile esters of 2,4,5-T were applied in March by helicopter.

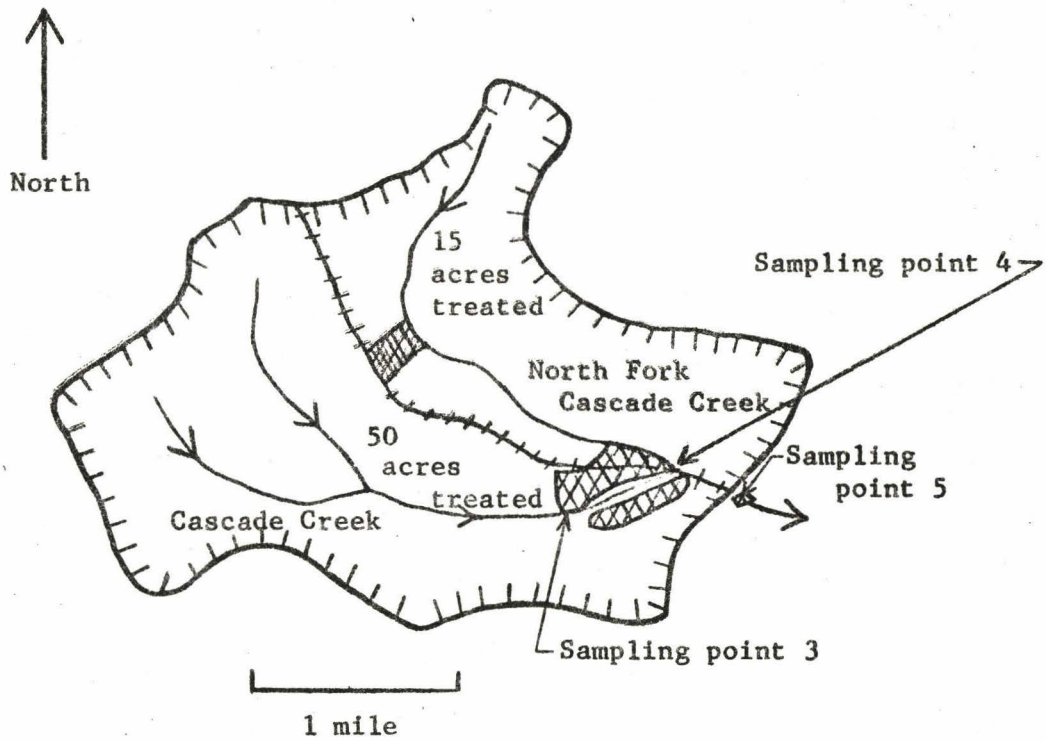


Figure 5.--Cascade Creek treatment area watershed. Sixty-five acres (2 percent) of a 3,450 acre watershed were treated with 2 lb/A 2,4,5-T.

Streams sampled at points 4 and 5 do not enter but run adjacent to the treated area. Point 3 samples a small stream from a 5-acre watershed which was completely sprayed. The results of analyses for herbicide residues in samples collected at points 3, 4, and 5 are in Table 1. Note the time of peak concentration and length of persistence. The last figure in the table is the last time a detectable residue was found. In all cases in the western Oregon study areas, sampling continued for 8 to 10 months with no residues encountered.

Table 1.--Contamination in the Cascade Creek Unit in parts per billion

Sample point 3[1]		Sample point 4		Sample point 5	
Hours after spraying	ppb 2,4,5-T	Hours after spraying	ppb 2,4,5-T	Hours after spraying	ppb 2,4,5-T
0.05	0	0.17	1	0.27	lost
0.62	16	1.33	2	1.40	3
1.28	7	2.2	1	1.40	3
2.0	4	3.9	1	3.9	0
4.0	4	5.4	0		
5.2	4				
9.8	4				
24.7	2				
48.2	1				
74.8[2]	1				

[1] Entire watershed feeding sampled stream was sprayed.
[2] Herbicide was detected for sixteen weeks at sample point 3.

The drainage basin at point 3 was characterized by a large slump and marshy area which indicates a high water table. The peak of concentration occurred shortly after application started, but low concentrations were found up to 16 weeks later. At points 4 and 5, however, quite different conditions prevailed. Only low levels of herbicide were found, and these persisted for less than one day. Data from points 4 and 5 reflect the small area of the watershed treated as well as the location of the treatment unit boundaries with respect to the sampled stream.

Other studies were carried out on the Malheur National Forest in eastern Oregon where rainfall of 10 to 15 inches per year prevails. The spray units in eastern Oregon were treated by helicopter with 2,4-D low volatile esters in early June (see Figure 6).

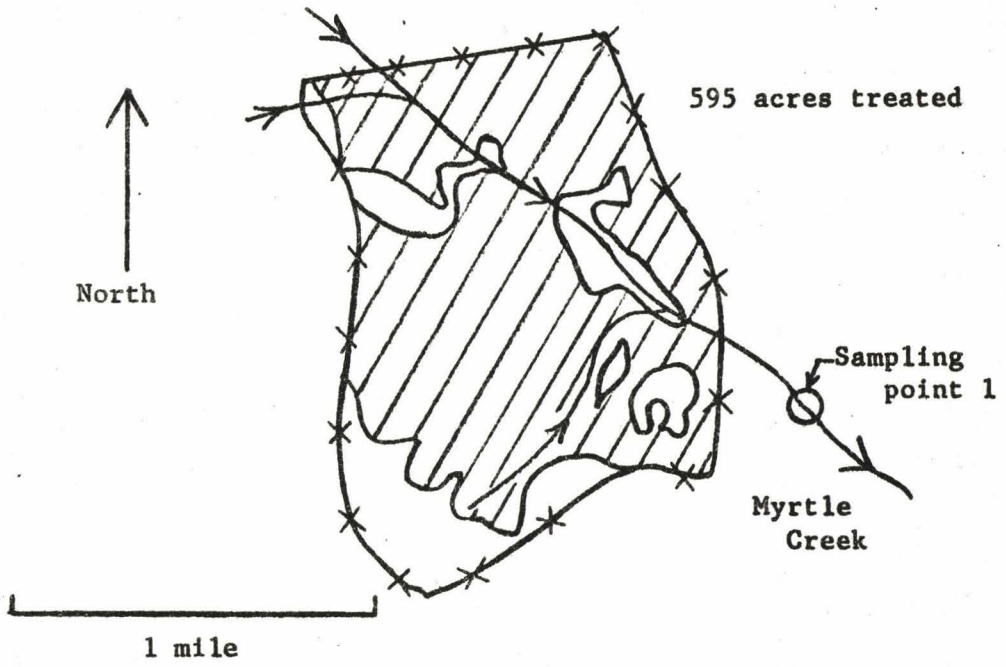


Figure 6.--West Myrtle treatment area - 595 acres treated with 2 lb/A 2,4-D.

Nearly 600 acres were treated in one block and a couple of live streams were included in the treatment area. The data from the sampling point are in Table 2.

Table 2.--Contamination in the West Myrtle Unit

Sample point 1	
Hours after spraying	ppb 2,4-D
1.75	132
3.7	61
4.7	85
6.0	10
7.0	26
8.0	75
9.0	59
13.9	51
26.9	3
37.9	9
78.0	8
80.8	1
1 week	T

The concentrations of herbicide were generally higher than those encountered in western Oregon.

What needs to be emphasized is that the magnitude of this short-term contamination is not a function of the herbicide or the geographical location in which it is used. The magnitude of contamination appears to be closely related to the manner in which the treatment area is laid out with respect to live streams. The following data from the Camp Creek spray unit in eastern Oregon illustrates these points most clearly.

Figure 7 shows the orientation of the Camp Creek unit to the sample stream. This sampling situation resembles situations frequently encountered in western Oregon where the spray boundaries were close to but did not include live streams.

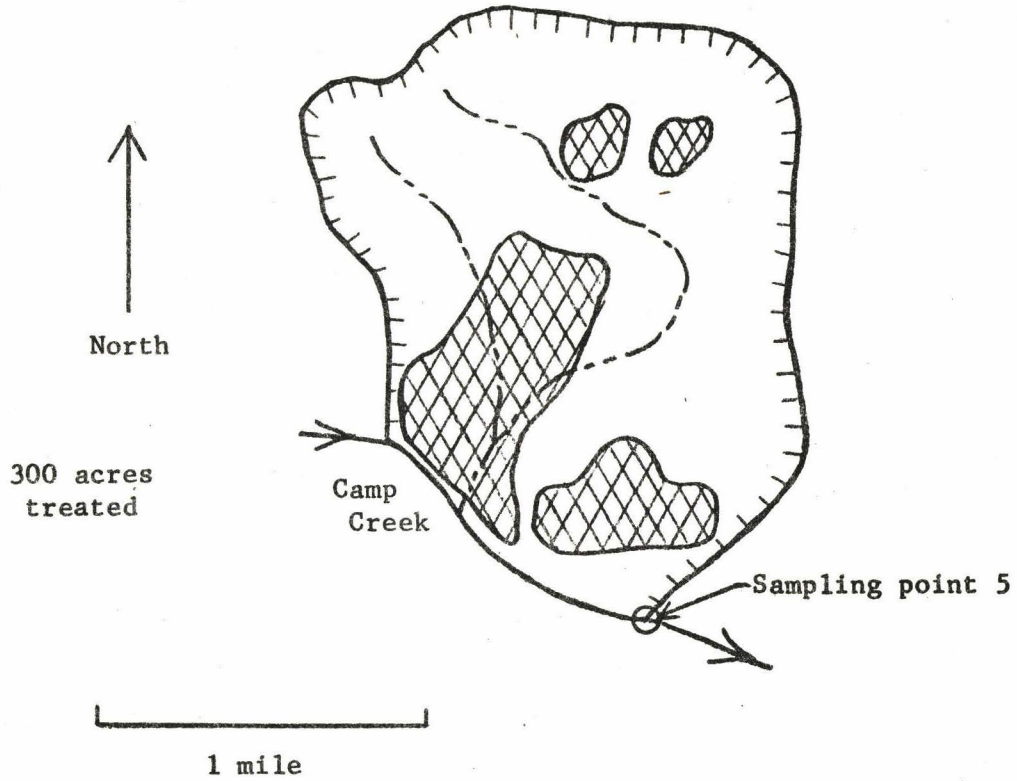


Figure 7.--Camp Creek treatment area watershed - 300 acres (23 percent) of a 1,300-acre watershed were treated with 2 lb/A 2,4-D.

The results in Table 3 show the concentration of herbicide was low, being of the order of magnitude found in western Oregon in the Alsea Basin study. These data further indicate that treatment area layout is the major influence on the degree of contamination.

Table 3.--Contamination in the Camp Creek Unit

Hours after spraying	ppb 2,4-D
0.05	T
2.0	25
5.4	1
8.7	1
84.5	3
1 week	0

Figure 8 shows the Keeney-Clark spray unit in eastern Oregon. This unit is a fairly flat, marshy area which contains several small live streams. Standing water was noted in several areas at the time of treatment in June which suggests a high water table. Data in Table 4 shows the consequence of treating such an area.

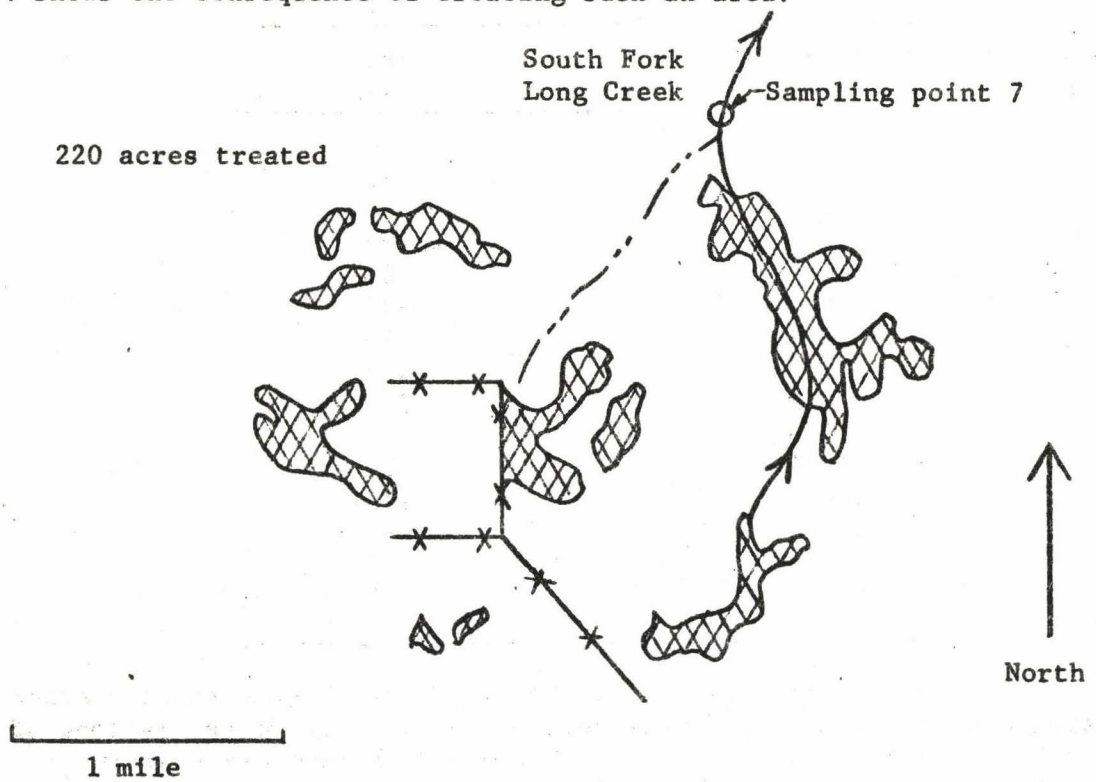


Figure 8.--Keeney-Clark meadows treatment area - 220 acres treated with 2 lb/A 2,4-D.

Table 4.--Contamination in the Keeney-Clark Meadow Unit

Sample point 7	
Hours after spraying	ppb 2,4-D
0.67	840
3.1	128
2.5	48
3.6	106
4.1	106
6.1	121
8.1	176
9.6	138
14.3	113
37.8	91
56.4	76
100.1	115
103.6	95
289.9	5
297.0	7

Very high concentrations of herbicide were found shortly after application. The long persistence of fairly high concentrations of herbicide are characteristic of what would be expected from areas of this type. The length of time measurable concentrations flowed from this area is unknown. This particular situation is probably one of the most dangerous in terms of potential stream contamination. A very slight rise in the water table could result in the release of very large quantities of herbicide to the streams which drain this area.

One point should be stressed. Short-term, high-level contamination results from direct application of herbicide to the water surface. This can markedly be reduced by excluding streams from treatment areas. In other words, if you do not want herbicide residues in the water, then don't put herbicides there.

There is need to consider the movement of herbicide into a stream. The amount of pesticide entering a stream from leaf fall or in rain washing materials from the air is probably not large enough to be of concern. The forest floor is one of the major receptors of aerially applied chemicals and is, therefore, a large reservoir of potential pollutants.

Any amount of herbicide that is not degraded or absorbed is available for leaching or surface runoff. Surface flow presents a potential hazard through the movement of herbicide to adjacent streams. Herbicide movement in surface flow is not restricted to movement in solution. Pesticides which are adsorbed can also be carried to streams on suspended silt, clay, or organic colloids.

While surface flow or mass overland flow has the potential to carry a lot of herbicide over a long distance in short time, leaching is slow and for most herbicides offers less danger of serious stream pollution. Let's consider the prospect of leaching versus surface flow. Figure 9 shows a diagrammatic valley exposing the soil profile.

The mechanism by which herbicides are moved from a spray deposit to the stream may be visualized as two competing reactions, leaching and surface runoff.

Rainfall that is not lost through evaporation either enters the soil profile or runs over the surface. In either case, it carries surface deposited herbicides either in solution or as suspended matter.

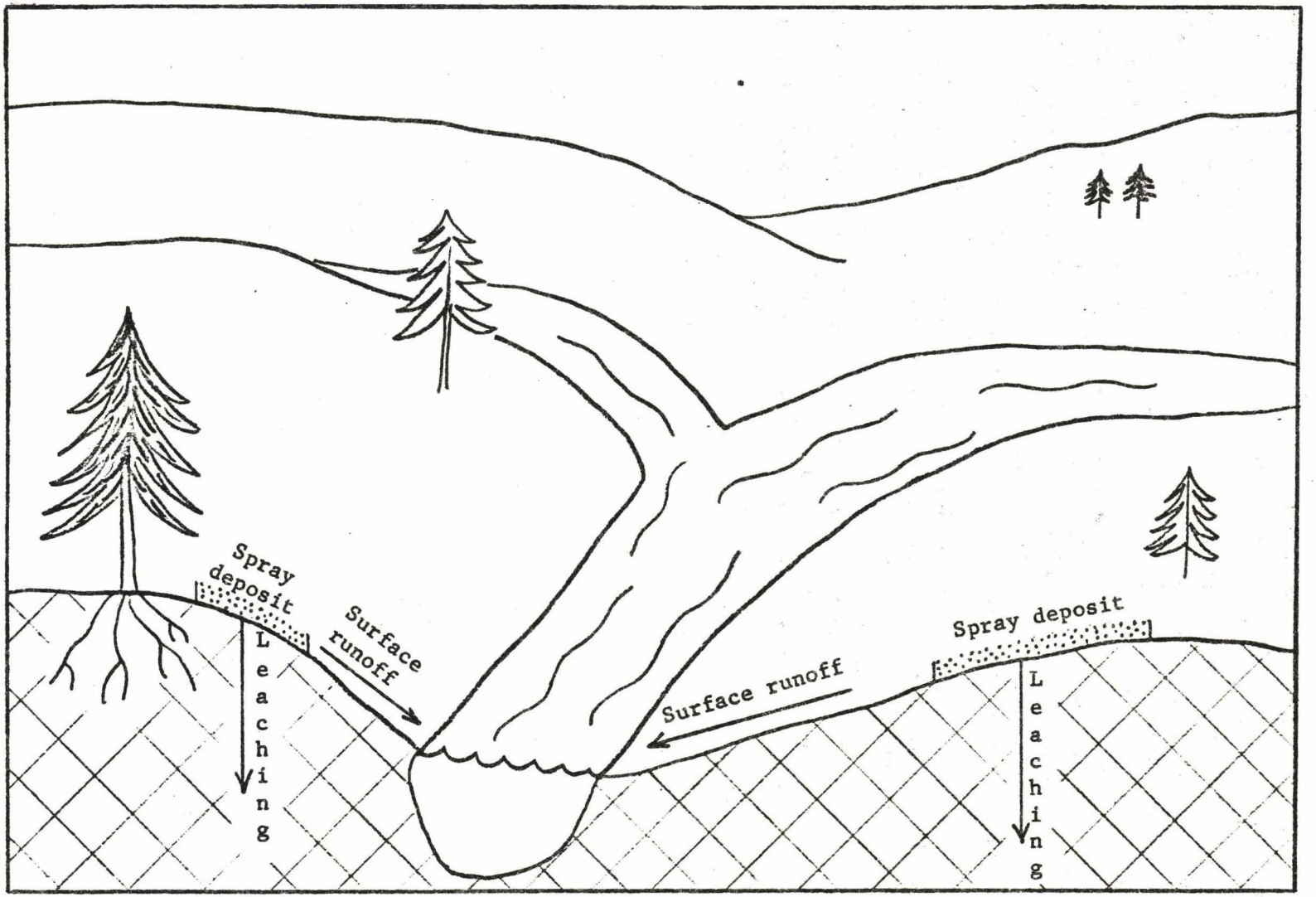


Figure 9.--Movement of chemicals to streams

The greater the proportion of water entering the soil profile the lower the proportion of water available for surface flow. In general, where the water goes the herbicide also goes. There are numerous factors which influence the distribution of water between surface flow and infiltration. Some of these factors are:

A. Nature of surface

1. Amount of surface organic matter
2. Slope
3. Depth of soil profile
4. Infiltration characteristics of soil
5. Immediate previous precipitation history

B. Nature of precipitation

1. Intensity
2. Duration
3. Form

These additional factors influence the amount of herbicide actually entering the stream due to surface flow:

1. Distance from stream course to closest point of herbicide application;
2. Infiltration properties of soil or surface organic matter;
3. Rate of surface flow;
4. Adsorptive characteristics of surface materials.

Any condition which retards the rate of discharge of oversurface flow to the stream will result in a decrease in the immediate level of contamination. It will also reduce the long-term total stream load of herbicide because a longer residence time in the soil will provide greater opportunity for degradation of the herbicide.

Long-term runoff was checked in a watershed in western Oregon treated with 2,4-D and 2,4,5-T in April. The Green Creek Watershed, 2,900 acres, (Figure 10) had many small treatment areas totaling 407 acres. No residues were detected (Table 5) even though sampling started after the first 1/2 inch of rain. Runoff of herbicide probably did not occur.

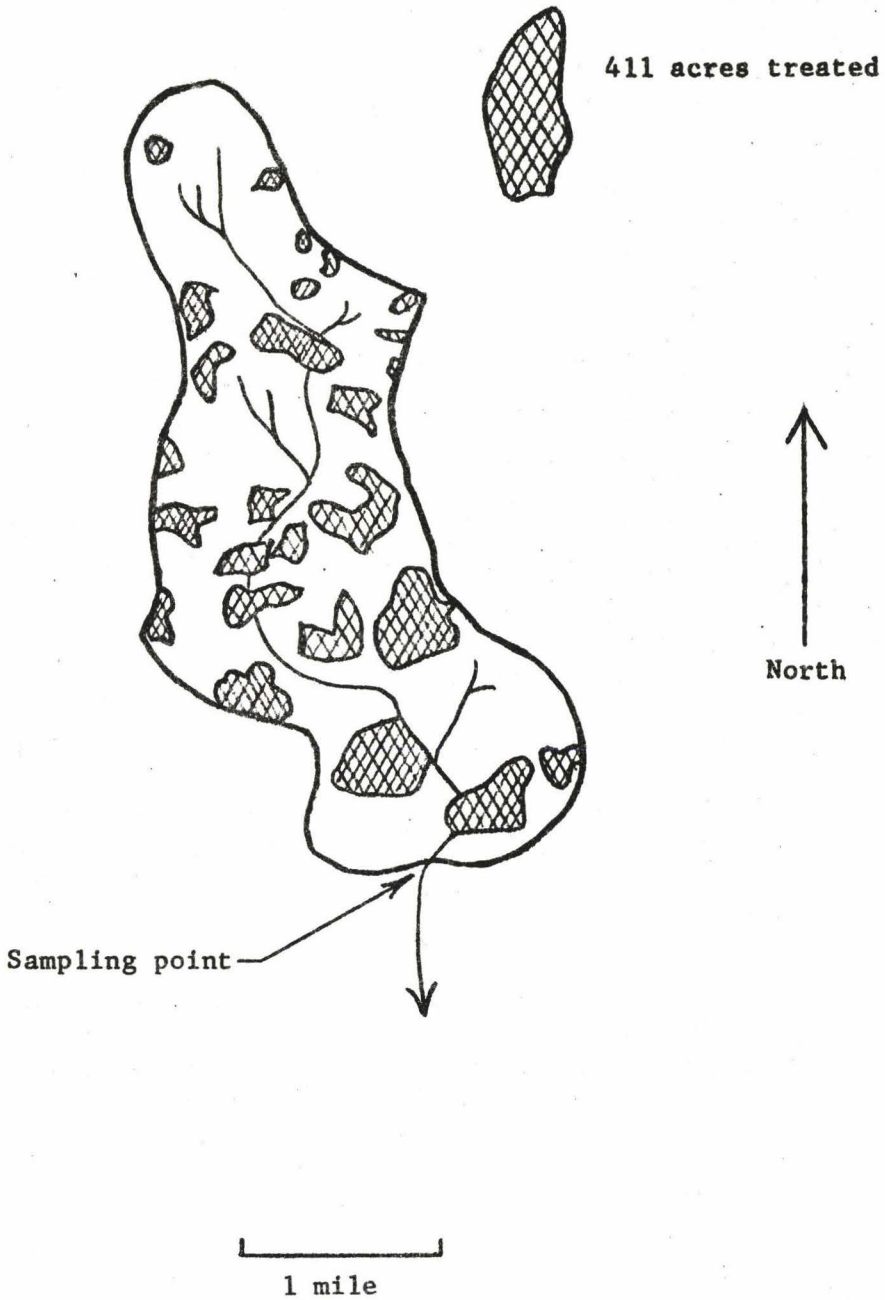


Figure 10.--Green Creek Watershed

Table 5.--Herbicide residues and rainfall patterns in the Green Creek Watershed

Date	Rainfall	Herbicide residues 2,4-D	2,4,5-T
	Inches	ppb	
September 29	0.6	---	---
30	0.4	0	0
October 1	1.0	0	0
2	0.6	0	0
3	3.1	0	0
4	0.0	---	---

Total rainfall this storm 5.7.

If we ignore direct application of chemicals to the water, these results indicate the movement of appreciable quantities of herbicides to streams on forest lands will be restricted to those special cases where overland flow of water occurs. It is the opinion of many hydrologists that overland flow is rare. If that is the case, then it is not surprising that residues have seldom been detected.

A lack of overland flow would also mean the precipitation is entering the soil profile taking the herbicide with it. Once in the soil, adsorption occurs, preventing rapid or extensive movement of the herbicide. The chemical moves much slower than the water through the soil.

This means the herbicide is available for degradation for a long period of time before sufficient movement would occur to permit release to a stream. It is only through degradation that the total load of environmental pollutants can be reduced.

POTENTIAL EXPOSURE

The potential exposure of an organism to a biologically significant dose is determined by two factors: (1) the initial distribution of the chemical among the four major components of the environment (air, vegetation, ground, and water) following application, and (2) the behavior of the chemical in each component of the environment. Initial distribution will be influenced by the rate and method of application, the properties of the chemical, and environmental conditions. The behavior of a chemical is the end result of its characteristic patterns of movement, persistence, and fate in and among the components of the environment. The size of the dose and the duration of exposure and, therefore, the nature of the response is determined by the initial distribution and subsequent behavior of the chemical. The behavior of the chemical (its movement, persistence, and fate) is determined by the interaction of the properties of the chemical with the properties of the environment. This interaction is guided by the laws of physics, chemistry, and biology to produce the behavior observed in the field.

Long-term chronic toxicity is important only when a chemical is retained by the organism for extended periods. If a compound is readily eliminated, the acute and short-term chronic toxicities will adequately describe its toxicity.

Feeding studies with various animals have shown that 2,4,5-T is rapidly excreted. Erne (1966) reported that the major route of elimination of 2,4,5-T from pigs, calves, and rats dosed with 100 mg./kg. was in the urine. Repeated doses did not result in retention or accumulation of herbicide. A cow which received 5 p.p.m. 2,4,5-T in its feed eliminated essentially all of the chemical within two days following exposure, and no 2,4,5-T was found in the milk (St. John et al. 1964). Mice injected with 100 mg./kg. 2,4,5-T eliminated approximately 70 percent within 24 hours. (Zielinski and Fishbein 1967)

Low residues of 2,4,5-T were found in blacktail deer up to 43 days after spraying (Newton and Norris 1968). The highest residues were found in the feces, urine, and stomach contents; negligible residues were found in body parts used for human consumption.

Evaluation of animal exposure to 2,4,5-T leads to the following conclusions:

1. Dairy and beef animals allowed to forage on treated grasses will ingest highest concentrations of 2,4,5-T shortly after application.

2. Because of degradation, growth dilution, and other factors, residues of 2,4,5-T will be markedly reduced a few weeks after application.

3. The herbicide is rapidly excreted; there is no accumulation in animal tissues.

4. There is no detectable residue in milk; therefore, man will not be exposed to 2,4,5-T through consumption of milk from animals foraging on treated grasses.

5. Long-term chronic exposure of wildlife should not occur since 2,4,5-T does not persist for long periods in the forest, and repeated applications are rare.

It is evident that the hazard of 2,4,5-T in the forest environment is low when the chemical is properly used. The reasons for this are: (a) the behavior of 2,4,5-T in the forest environment makes it unlikely that organisms will be exposed to acutely toxic or lethal doses of chemicals, (b) the rapid excretion of ingested 2,4,5-T lessens the likelihood of undesirable effects, and (c) the comparatively short persistence of 2,4,5-T in the environment precludes the possibility of prolonged exposure.

HAZARD TO MAN

The public is greatly concerned and rightly so, about the hazard to man, his animals and wildlife. The present furor over the use of 2,4,5-T is caused by reports from Viet Nam and a few studies on laboratory animals which also indicate a possible teratogenic impact. These are related to possible teratogenic (birth defects) impact on the human population. However, these studies have not yet been made available to the scientific community for critical review. Hence, valid interpretations and extrapolations from laboratory to field conditions are not possible.

In most laboratory studies the animals were given massive doses in carriers not used in field formulations. This adds to the difficulty of evaluating the study results and relating them to the exposure man and animals receive under normal conditions of use.

When used in the forest according to approved procedures, 2,4,5-T offers minimal hazard to man and his environment because the large and prolonged doses required to cause significant biological effects do not occur.

PART III - THE SIUSLAW STORY

This is a case history where herbicides were used in a responsible manner under strict supervision. Streams were avoided, minimum dosages were used, the water was monitored, sensitive areas were avoided. The projects were carefully reviewed with concerned public agencies and private citizens and were done with their concurrence. The Siuslaw National Forest uses the concepts previously discussed to formulate an effective program of chemical brush control.

The Siuslaw National Forest Herbicide Program serves as an example as to how herbicides can be used skillfully and responsibly.

The Siuslaw National Forest is located in the Coast Range west of Corvallis, Oregon, where generally deep sandy soils, abundant rainfall and long growing seasons result in rapid growth rate of coniferous timber. However, these same factors also combine to produce luxuriant stands of hardwoods and brush species that, following timber harvest, compete strongly with the new trees for growing space.

This National Forest is successfully practicing chemical brush control measures to assure full stocking of the har ested areas at the earliest possible date. The chemicals used and rates of application have been carefully tested under a wide variety of conditions.

The Siuslaw National Forest has about 444,000 acres of second-growth conifers, 158,000 acres of pure hardwoods or mixed stands of hardwoods and conifers.

At present, the sustained yeild harvest is 348 million board feet of timber annually. In order to continue to harvest this volume, it is necessary each year to clearcut about 6,000 acres and partial cut an additional 5,000 acres.

Many attempts have been made in the past to reforest clearcut areas without preparing the ground. The majority of these efforts failed because of invasion by brush species. In recent years, fire has been used whenever possible in site preparation. Fire is a successful tool, but it is looked upon with increasing disfavor because of smoke pollution. Sometimes the green brush is so dense that fire from logging slash will not spread. In these cases, herbicides are often used to partially kill the brush. The resulting increase in flammability improves chances to secure clean burns that speed regeneration of conifers.

If burning cannot be accomplished, then herbicides are used to control brush as a site preparation measure. In some circumstances, herbicides are also used to release planted trees from brush encroachment and regrowth of brush.

In cases where slash disposal by burning does result in good site preparation, mineral soil is exposed. Under these conditions, alder growth will exceed that of conifer species during the first few years. Thus, even where slash burning prepares a good planting site for conifers, herbicides often are used to release the planted trees from brush competition.

Simply stated, the primary timber management goal on the Siuslaw Forest is to (1) promptly reforest every acre harvested so that the full growing capacity of the land will be utilized and, (2) to convert the present low-producing alder and mixed conifer stands to nearly pure conifer stands as rapidly as possible.

The Siuslaw National Forest has the biological capacity to produce an average of about 1,000 board feet per acre, per year, on a 100-year rotation. However, this capacity requires that stocking of at least 250 conifers per acre must be established promptly after harvest and that brush competition shall be controlled for at least six years to assure freedom for the young trees to grow. If this is done, the Siuslaw National Forest can, within the guidelines of multiple use, gradually increase the present sustained yield harvest from 348 million board feet per year to about 500 million board feet per year.

On the other hand, if brush and alder are allowed to encroach and occupy the land, it is estimated that the sustained yield capacity of the Forest would be reduced to approximately 200 million board feet per year. As compared to the full potential growing capacity of about 500 million board feet per year under intensive management, this reduced sustained yield harvest would be equivalent to withdrawing nearly the full volume of the present allowable sustained yield harvest.

Without intensive management, the harvest will be reduced by nearly 300 million board feet. By intensive management, the Siuslaw can maintain an annual harvest of about 500 million board feet. The herbicides are major tools in the intensive management of the Forest, and are needed to maintain this additional harvest of 300 million board feet per year.

When plantations are taken over by brush, there are three management choices: (1) allow alder to occupy the site; (2) reclaim the brush by mechanical brush disposal, fire, chemical treatment, or some combination of these practices; (3) accomplish release of individual trees by repeated hand work.

Timber should only be harvested at the rate at which it can be grown. To continue to harvest heavy volumes when reforestation fails or is delayed is gross mismanagement.

The Siuslaw National Forest recognizes and accepts the need to protect the environment, and that the public is vitally concerned about pesticide usage. They take the following steps in successfully conducting their projects:

1. Discuss projects with municipal water boards and secure acceptance.

2. Advise the Oregon State Game Commission and Fish Commission and the State Board of Health and solicit comments. Advise the Bureau of Sports Fisheries and Wildlife and ask for advice. Advise Oregon State University.

3. Locate all private water systems that could be affected by the projects and discuss with concerned persons the application rates, procedures and control measures.

4. Attend local meetings and discuss the projects with local groups and key individuals.

5. Work with key people yearlong; this cannot be accomplished during the last few weeks before projects begin.

The following controls are established to insure that the job is done with a minimum impact on the environment:

1. An unsprayed buffer zone at least 100 feet wide is left adjacent to live streams and/or private property.

2. Flights with spray mixtures over and across private properties, rivers and lakes, recreation sites and highways are forbidden.

3. Spraying marshes, ponds or other water impoundments is not permitted.

4. Empty containers are returned to the Ranger District office for disposal. Eventually they are crushed and buried.

5. Only the chemical to be used during that day is carried in a vehicle. Any excess must be returned to the ranger headquarters at night. The chemicals and unused mixtures are the complete and sole responsibility of the Forest Service, not the contractor.

6. Sensitive areas such as critical fish habitat, water intakes and property boundaries are flagged with high-visibility markers.

7. Critical areas are reviewed and known to the Forest Service contract inspector prior to spray operation.

8. There is an inspector on each spray unit during the full time required for the spray operation. Spraying does not begin until the aircraft pilot is given the go-ahead by the Forest Service inspector.

9. Pilots are furnished with photographs and maps showing the required flight lines.

10. Every gallon of herbicide used is accounted for and its use documented. Detailed records are kept.

11. All mixing and batching operations and loading of spray mixtures on vehicles or aircraft is restricted to locations outside of municipal supply watershed boundaries unless some peculiar situation makes this impossible.

12. Equipment is not cleaned in municipal supply watersheds.

13. Spraying is not done when wind velocities exceed 6 miles per hour.

14. Spraying is not done when flight conditions are impaired by rain, ground fog or turbulence.

15. Spray flights are restricted to not more than 45 feet above vegetative cover.

16. Water samples for chemical analysis are taken at preselected locations before, during, and after the spray operation. Through a cooperative agreement, the chemical analyses of these samples is made on a fee basis by the State Chemist.

17. Adjacent property owners are encouraged to view the operation. Fish hatchery personnel and municipal supply board members are notified of actual project operations.

The Siuslaw Forest evaluation of the chemical brush control program indicates that the various projects have been 90 percent successful in alder control and 70 percent successful in salmonberry control. There is no known instance of toxic damage to domestic or game animals or to fish life. Extensive water monitoring and chemical analysis of samples taken indicate that there were no adverse effects on domestic water supplies which originated in or flowed through treated areas.

The Forest Service continues to seek alternatives to herbicides as a means of brush control. In the meantime, the least hazardous herbicide available will be used. The cost of herbicide brush control is approximately $15 per acre.

Why are all these precautions observed? The answer is simple. Herbicides improperly used can be a hazard to man and to the environment. Strict controls insure a uniform application of the herbicide in the minimum concentration to accomplish satisfactory brush control and to avoid hazard to man, wildlife, and the environment.

The Forest Service believes that modern technology and tools can be properly and safely used in a responsible manner to maximize the productivity of our National Forests.

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